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Portland Study

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The Portland Study

by

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Test and Evaluation Branch
Emission Control Technology Division
Office of Mobile Sources
U.S. Environmental Protection Agency

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This report describes the two phases of the Portland Study, a contractor operated vehicle emission test program that was conducted in Portland, Oregon, over a five-year period beginning in 1977. The report includes information on the history of the program, the objectives of the various tasks that were completed, program design, and some of the problems encountered.

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Summary

The Portland Study encompassed a series of test programs conducted for EPA by a contractor in Portland, Oregon from September 1977 through April 1982. The objectives of the major programs were to study the correlation between short inspection tests and the Federal Test Procedure, to study the emission-reduction effectiveness of an operating vehicle inspection-maintenance (I/M) program, and to study post-I/M deterioration. Other important tasks completed in the Portland Study included an Emission Factors test program, an evaluation of the effectiveness of mechanic training, a study of the effect of I/M on light-duty trucks, and evaluations of the in-use performance of three-way catalyst emission control systems.

A total of 8,465 emission test sequences were conducted (all of which included at least the FTP and various short tests), at a cost for the two contracts of $5,258,328.

Data are on magnetic tape in Ann Arbor under the cognizance of either Test and Evaluation Branch (TEB) or I/M Staff personnel. Included are mass emissions and tailpipe concentration data, vehicle descriptions, maintenance information, vehicle owner questionnaires, diagnostic and repair information, and so on. Portland Study data have been discussed in I/M Staff reports, TEB reports, and papers presented to the Society of Automotive Engineers and the Air Pollution Control Association.

Introduction

This report describes the two phases of the Portland Study, a contractor-operated vehicle emission test program that was conducted in Portland, Oregon, over a five-year period beginning in 1977. The report includes information on the history of the program, the objectives of the various tasks that were completed, program design, and some of the problems encountered. It does not include any test results, which may be found in contractor test reports available from the library at the EPA Motor Vehicle Emission Laboratory in Ann Arbor, Michigan. Test data and other information are also stored on magnetic tape under the cognizance of I/M Staff and Test and Evaluation Branch personnel in Ann Arbor.

Motor vehicle emission inspection and maintenance has been recognized for years by EPA as an integral part of the total approach toward reducing exhaust emissions from motor vehicles. In late 1975, a study was conceived by Characterization and Applications Branch (CAB) personnel for examining two major areas, of interest with respect to I/M programs. These areas, on which very little data were available, were: 1) the emission data correlation between the offical EPA test for measuring exhaust emissions (the cold start Federal Test Procedure) and the various simple, short inspection tests that would be used in I/M programs; and 2) the effectiveness of an operating inspection program in terms of identifying high-emission cars, emission reductions due to repairs, costs, and the emission histories of cars subject to I/M programs.

At the time the study was being designed, I/M programs were operating in the state of New Jersey and in the metropolitan area of Portland, Oregon. Both were considered to be acceptable sites for the study. Portland was chosen because of slightly lower costs, and because a question had arisen as to whether the New Jersey Inspection program was going to continue.

I. Short Test Correlation and Effectiveness Study

Contract Information

Title: Short Test Correlation and Effectiveness Study
Contract No.: 68-03-2513
Contractor: Hamilton Test Systems, Inc.
Cost: $3,135,983
Number of Tests: 5,874
Period of Performance: February 3, 1977 through July 9, 1979 (except for Final Report)

Objectives

The Portland Study as originally planned consisted of two parts or elements. The objective of Element I was to determine the correlation between the Federal Test Procedure, conducted under laboratory conditions, and various short tests that might be used in actual inspection programs. Such correlation was necessary in order to implement the emission performance warranty provisions of the Clean Air Act (Section 207(b)).

The objective of Element II was to evaluate the effectiveness of an operating I/M program (that run by the Oregon Department of Environmental Quality) (DEQ). The evaluation was in terms of the idle test's ability to identify gross emitters, the effectiveness of the repair industry in reducing emissions, and the deterioration of emissions over a one-year period.

Well into the program a third element was added. The objective of Element III, the post-I/M deterioration study, was to collect information on deterioration of emissions over short periods of time after passing an inspection test.

Chronology

12-08-75	CAB personnel initiated Procurement Request for "Short Test Correlation and Effectiveness Study." Estimated cost: $2.8 million.
06-11-76	Request for Proposal No. CI 76-0070 issued by Negotiated Contracts Branch
06-24-76	Bidders' Conference held in Portland
07-26-76	Amendment to RFP issued: Contract type changed from Cost Plus Fixed Fee to Firm Fixed Price
	Proposal submittal date moved back two weeks, from 08-09-76 to 08-23-76
	Minor Scope of Work changes in response to questions raised in Bidders' Conference
08-23-76	Proposal received (one offeror only)
09-23-76	CAB Technical Evaluation completed
10-22-76	Received HTS clarification of questions raised in Technical Evaluation
11-24-76	Cost Advisor's Report received
12-08-76	Meeting with HTS and NCB in Cincinnati to discuss source of Element II control fleet
12-15/16-76	Negotiations in Ann Arbor on Scope of Work
01-15-77	Agreement achieved on Firm Fixed Price: $2,730,000
02-03-77	Contract signed
04-11-77	EPA personnel arrived in Portland to set up Project Office
04 and 05-77	Modification of test facility, installation of test equipment, training of personnel

05-11/12-77	Meeting in Ann Arbor to resolve data handling problems
08-26-77	HTS terminated contract with OLI (testing subcontractor)
09-20-77	First emission test successfully completed
09-01-78	Short tests by DEQ inspectors halted.
01-22-79	Element III testing began
01-24-79	Element I testing halted (1950 tests)
04-02-79	Element II testing completed (3220 tests)
07-06-79	Element III testing completed (704 tests)

Program Design

Element I

For the Element I correlation study, 59 test vehicle groups or cells were chosen to represent the national fleet of 1975-77 model year passenger cars. The cells were defined by model year, manufacturer, engine, transmission and vehicle weight. Considering statistical validity for the intended short test-FTP correlation, the minimum sample size for each cell was set at 40 vehicles. The criteria by which the cells were defined included: the widest possible coverage of vehicles and engines, quantities produced, technological significance, likelihood of future production, and availability in the Portland area. The test sequence included idle and other short tests conducted at a DEQ inspection station, the same tests at the HTS facility, and the FTP.

Originally, there were to be 2400 cars tested for Element I, of which 220 would also be involved in the Element II effectiveness study. As the program developed, it was necessary to recruit many replacements for participants who dropped out of the Element II program. Also, Element I testing was halted ahead of schedule when I/M Staff data analysis indicated that sufficient data on FTP-short test correlation had been collected. This resulted in a total of 2207 tests for Element I. Of these, 1950 cars were tested exclusively for Element I, and 257 were involved in both Element I and Element II.

Element II

For the Element II effectiveness study, a fleet of cars from Portland (subject to I/M) and a similar fleet from Eugene, Oregon (non-I/M area, to serve as the experimental control) were tested initially in as-received condition and then at three month, i.e., quarterly intervals for one year. An additional test was conducted on Portland cars initially failing the DEQ inspection, following repair sufficient to enable the car to pass the inspection. Thus, Element II testing produced emission histories of cars subject to I/M for comparison with the histories of cars not subject to I/M. In addition, the effectiveness of repairs to failed cars, done in the repair industry at the car owner's expense, was clearly shown. The test sequence included the FTP, HFET, hot start FTP, and various short tests.

The test fleet of 660 cars was divided into model year groups 1972-74 and 1975-1977, the composition of each group reflecting Oregon registration figures. Within each model year group, about 110 Portland cars passed the DEQ inspection, 110 Portland cars failed, and 110 were from Eugene. Element II attrition was significant: 7% to 9% of the cars remaining in the program dropped out each quarter. As a result, over 50 cars had to be recruited to replace those whose owners dropped out of the program. A total of 715 cars were initially tested and 506, or 71%, received the fourth quarterly retest. By contractual requirement the total number of Element II tests was 3220.

Early in the follow-on contract, second, third, and fourth quarterly retests were conducted on 1975-77 Portland cars to improve the Element II data base. This brought the completion total to 527 cars, or 74%.

Element III

The element III post-I/M deterioration study was a negotiated-price modification to the original contract. The Element III test fleet consisted of 292 privately owned cars of 1975-77 model years in rough proportion to the Oregon registered population of those model years, but with sample sizes of five minimum and nine maximum. The recruiting objective was to start the test program on each car at the beginning of its biennial registration cycle rather than at an unknown point as in the case of Element II. Owners were contacted at the time their vehicles were due to be reregistered and therefore due for a "real" DEQ inspection. This was accomplished by recruiting on the basis of vehicle model year and the first letter on the license plate, which indicates the month in which the car was registered.

The initial test was in as-received condition. Retests were at one, two, or three month intervals for each third of the test fleet, respectively. Cars were entered in the program without regard to their DEQ pass/fail status, and it turned out that 113 (39%) were DEQ fails. The owners of those cars were asked to have the cars repaired to pass the DEQ inspection (108 did so) and the cars were retested after the repair.

If a vehicle showed significant deterioration of emissions on the one, two, or three month retest, the owner was interviewed to possibly establish the reason. With the owner's permission the car was tuned by the contractor to manufacturer's specifications, tested, and retested after one month. There were fourteen such cars. A total of 704 tests were run in Element III.

DEQ Support

An important phase of the Element I correlation study was to have short inspection tests conducted by state employees at a state inspection station. To this end the Oregon DEQ was awarded a contract, "Support to Correlation and I/M Study," to provide space at an inspection station for test equipment installed by HTS, and to provide the services of state inspectors to conduct inspection tests on Element I cars using that equipment.

Because of changes in EPA policy on the need for correlation between the FTP and loaded inspection tests, the contract with the Oregon DEQ was terminated by EPA on September 1, 1978. By that time 1182 cars had been tested by the DEQ personnel. The total cost of the contract was $100,500.

Problems

As might be expected with a project of the size and scope of the original Portland Study, there were numerous problems. The most important ones will be discussed here, roughly in chronological order.

Element I Vehicle List

The original vehicle list that appeared in the RFP and the contract consisted of 2400 cars of 1975-76 model years. They represented the four major U.S. manufacturers plus 20 foreign marques including Alfa Romeo, MG and Triumph. Sample sizes for various vehicles ranged from 5 to 100. Shortly after the contract was signed the CAB Branch Chief determined that testing 1977 models would be desirable. Further, for statistical validity of the desired FTP-short test correlation, the minimum sample size for a given vehicle type (defined as a combination of manufacturer, engine, transmission, and weight class) had to be 40.

The Element I test fleet was completely redesigned, using criteria including: the widest possible coverage of vehicle and engines, quantities produced, technological significance, likelihood of future production, and availability in the Portland area. Because the contract was for a Firm Fixed Price, this change had to be accomplished by a contract modification.

Data Formatting and Handling

Early on, a major problem developed over EPA's requirements for data collecting and formatting as revealed in the EPA proposed data formats. These had the effect of increasing the contractor's equipment and personnel requirements beyond its contractual responsibilities. After considerable discussion and negotiation, the data collecting, handling, and formatting requirements were agreed to. The main elements of the agreement were that HTS would collect the additional data required by EPA and rearrange all data into EPA's formats, using an EPA-paid account on the Michigan Terminal System. HTS would supply terminals and teleprinters both for itself and the EPA Portland Study project office. The agreement was documented as contract modification number 3. This data handling system worked well for as long as it was used.

Program Delays

The contractor's original plan of performance was that equipment would be installed in May 1977, with testing beginning in June at the rate of 20 tests per day. The actual program startup was much more time-consuming, and the testing reached 20 per day only by July 1978. Problems were numerous. Calibration gases and chassis dynamometers were delivered on schedule, but other test equipment was a month late. Installation and checkout were complicated by wiring and plumbing mistakes in the analyzers. These problems were aggravated by the inability of the testing subcontractor (Olson Laboratories, Inc.) to organize and manage the work it had to do. In late August 1977 HTS terminated its contract with OLI and assumed the responsibility for vehicle testing operations. A new plan of performance was submitted showing a gradual buildup of the testing rate as equipment was made operational and new test technicians were trained. The first official test, which became part of EPA's data base, was run on September 20, 1977. These delays caused the program to slip several months behind the

original schedule. EPA thus had to spend additional money on its office space in Portland and on its contract for support from the DEQ. To cover EPA's extra expenses, a downward adjustment in the price of a later modification to the HTS contract was negotiated.

Vehicle Recruiting

Vehicle recruiting went very well in terms of the public's response to the HTS recruiting letter. Problems did occur with respect to the makeup of the fleet in both Element I and Element II. In Element I, HTS recruited off the top of the registration lists for each cell, which resulted in a lot of vanity plates and letter-A license plates getting into the program. HTS also recruited makes in bunches, in violation of a contractual requirement. At one point 19 cars had been tested in one cell and none, or only a few, in several other cells. The ideal was to have the Element I cells be filled evenly, with cars of various license plate first-letters, over the entire 10 months of Element I testing so that climatic effects in the short test to FTP correlation could be seen for all the cells. Technical directions and a contract modification finally got HTS squared away but not before much distortion had occurred. At the end of Element I testing, sample sizes ranged from 32 to 45, where the ideal would have been 37.

The same vanity plate and A-plate problems occurred in Element II. A bigger problem had to do with the Element II program design. Vehicles were recruited for Element II at any point in their two-year Oregon registration cycle; the ideal would have been to recruit them at the beginning of that cycle. (An EPA remark in the Bidders' Conference indicates that such was EPA's intent.) Unfortunately it was never clearly stated in the RFP or the contract. The result was that cars were recruited off registration lists without regard to when they were last inspected by DEQ. Therefore, the emissions history of a car in Element II could be interrupted by maintenance sometime during the one-year study if the car needed it to pass the DEQ inspection. Thanks to Element III and its continuation in the follow-on contract, data did become available on cars in the first year after they passed the DEQ inspection. Also to help with Element II data analysis the Oregon Motor Vehicle Division was engaged to look up registration dates on Element II cars.

Data Packet Error Rate

The contractor's original proposal stated that the same Hewlett-Packard computer used to present driving cycles and to switch valves for CVS bag filling would also select gas analyzer ranges, zero and span the analyzers, read sample bag concentrations and CVS inputs, and calculate mass emissions. This capability was never achieved in spite of attempts by both OLI and HTS. The idea of hiring the H-P programming service was rejected by HTS on the grounds of cost. As a result the HTS data flow system included a large number of manual entries and interfacing, and manual checking. The HTS data review process was insufficient to ensure delivery to EPA of error-free data.

The error rate was very high for several months - from September 1977 through April 1978 over one third of the data packets submitted contained error, and there was no trend of improvement. After EPA began simply returning erroneous packets, instead of also including a description of the error, HTS finally seemed to attend to the problem. By June the error rate was down to an acceptable 10%.

Contract Modifications

Because this was a Firm Fixed Price contract, it was difficult to change the Scope of Work, as EPA found it necessary to do several times during the course of the program. For each change the entire procurement cycle was involved: preparation of procurement package, evaluation of HTS response, price negotiation and so on. This often led to delays in the implementation of the desired changes.

II. Testing Support for Evaluation of I/M Issues

Contract Information

Title: Testing Support for Evaluation of I/M Issues
Contract No.: 68-03-2829
Contractor: Hamilton Test Systems, Inc.
Cost: $2,122,345
No. of Tests: 2591
Period of Performance: June 10, 1979 through April 14, 1982 (for testing operations)

Objective

The objective of the program was primarily to provide EPA with the capability of quickly obtaining emission data and other information to answer questions and resolve issues that might arise as I/M programs were planned and implemented around the country. In general the data were to come from in-use, privately owned light duty vehicles recruited in Portland, where an I/M program had been in operation since 1975. In addition, the contract would provide a site for other testing requirements which could not be handled by the EPA Motor Vehicle Emission Laboratory at Ann Arbor, Michigan. A total of 1951 tests were conducted for I/M support purposes.

As the program developed and testing requirements were defined by IMS and TEB personnel, a significant number of tests were conducted for which I/M was not the rationale. These included tests to study fuel economy discrepancies between in-use and EPA values, tests on cars from a non-I/M area (Vancouver, Washington) for the Emission Factors data base, and evaluation of a fuel economy retrofit device. Additional tests under the Project Officer's direction were also run to evaluate alternate fuels, retrofits and other systems, primarily at the request of government agencies in the Portland area. A total of 640 non-I/M oriented tests were conducted.

Chronology

12-19-78	TEB personnel initiate Procurement Request for "Testing Support for Evaluation of I/M Issues"
03-28-78	RFP No. CI 79-0118 issued (Sole Source Procurement)
04-16-79	HTS proposal received
05-04-79	TEB Technical Evaluation completed
06-10-79	Work begun under Anticipatory Cost Letter
07-26-79	Effective date of contract
04-15-82	End of testing operations

Program Design

The contract type - Cost Plus Fixed Fee - made it relatively easy to give technical direction to HTS, within the general specifications of the contract. The assigned tasks, called Test Groups in the contract, were described in Technical Directions which included instructions in these areas:

Vehicles to be recruited
Recruiting methods
Sequence of tests to be run
Data to be collected
Criteria for performing maintenance and retest

Seventeen Test Groups were specified. All except No. 15 required the two-speed idle test conducted by the Oregon DEQ, the FTP, the Highway Fuel Economy Test, two to five chassis dynamometer short tests, and underhood and diagnostic inspections. In some sequences in Test Group 8, the FTP was replaced with the hot start FTP.

On Test Groups 14, 16, and 17, test data including emissions concentrations were entered on EPA-specified forms and sent to Systex, Inc., EPA's data reduction contractor. On all other Test Groups, test information including mass emissions and fuel economy data were transmitted via telephone to MTS, reformatted, and made available to EPA.

Test Group Descriptions

Following are brief descriptions of the tasks completed in the program.

Test Group 1 - Restorative Maintenance on Three-Way Catalyst Vehicles

Three-way catalyst cars of 1978-79 model years tested as received and after restorative maintenance. 51 cars, 74 tests.

Test Group 2 - Element II Continuation Tests.

Quarterly retests were continued on 1975-77 Portland cars from Element II to increase the number of cars completing the full one-year series of tests. 22 cars, 50 tests.

Test Groups 3 and 4 - Element III Retests

Element III cars were retested at intervals of 6, 9 and 12 months after the initial test. Cars failing the DEQ inspection at the 12-month point were given restorative maintenance and retested. 258 cars, 743 tests.

Test Group 5 - Effectiveness of EGR Repairs

Element II cars with defective EGR systems were tested as received, after EGR repairs, and after six more months of service in the owner's hands. 28 cars, 80 tests.

Test Group 6 - Heated Air Intake Disablement

Cars from the contractor's loaner fleet (1979-80 model years) were tested to study the effect of disabling heated air intake systems. 10 cars, 20 tests.

Test Group 7 - Mechanic Training Evaluation Program

The objective of this program was to evaluate the effect of mechanic training on emission reductions achieved in an I/M program. The training consisted of the Colorado State University emission repair course.

Cars failing the DEQ inspection were tested as-received, after repair by the participating mechanics, and after restorative maintenance by the contractor. Matched sets of cars were tested this way before and after the training course was given, in a blind study. 98 cars, 307 tests.

Test Group 8 - Evaluation of Potential Catalyst Diagnostic Tests

Cars from the contractor's loaner fleet were tested to evaluate the usefulness of various short tests in identifying lead-poisoned catalytic converters. 3 cars, 43 tests.

Test Group 9 - Vancouver Versus Portland Vehicle Emissions

Matching cars (1976 and 1978 model years) from the two cities were tested as-received to compare emissions from I/M and non-I/M areas. 212 cars, 212 tests.

Test Group 10 - Effect of Specific Maintenance Tasks on Emission Repairs on I/M Failed Vehicles

Test Group 9 Vancouver cars that failed the DEQ inspection as-received were repaired in specified steps by the contractor and retested. 35 cars, 41 tests.

Test Group 11 - Fuel Economy Shortfall Tests

Twenty types of 1978-80 model year vehicles (including four light duty truck models) were tested to provide information on the discrepancies between in-use fuel economy and the EPA Buyer's Guide values. The sample size for each type was between 5 and 7 vehicles. The vehicles were tested as-received; those failing to meet Federal emission standards were also tested after restorative maintenance. 129 vehicles, 219 tests.

Test Group 12 - Effect of I/M on Light Duty Trucks

Light duty trucks of 1976, 1978 and 1980 model years were tested in as-received condition. Those failing the state inspection were repaired commercially and retested. Selected vehicles were also given restorative maintenance by the contractor and retested. 105 vehicles, 148 tests

Test Group 13 - Evaluation of 1981 Ford Open-Loop Three-Way Catalyst Cars

Open-loop 1981 Ford products were tested in as-received condition. Those exceeding specified levels on the FTP or certain short tests were given restorative maintenance and retested. Four cars were given a series of tests using various fuels and with disablement of emission control systems. 112 cars, 179 tests.

Test Group 14 - A Study of Emissions From Light-Duty Vehicles in Vancouver, Washington.

Vehicles of 1978-82 model years from Vancouver were tested in as-received condition as part of the Emission Factors data collection program. Those failing to meet certain emission criteria were retested following restorative maintenance. 300 vehicles, 340 tests.

Test Group 15 - Evaluation of "Super-Mag Fuel Extender".

This device evaluation was conducted pursuant to Section 511 of the Motor Vehicle Information and Cost Savings Act. 3 cars, 34 tests.

Test Group 16 - Problem Closed-Loop 3-way Catalyst Cars

As-received and after-maintenance tests were performed on closed-loop 3-way catalyst cars with known or suspected problems in those systems. 6 cars, 10 tests.

Test Group 17 - Disablement Testing of Closed-Loop Systems

Closed-loop cars were tested to evaluate the effects of various disablements on FTP and short test emissions. 22 cars, 80 tests.

In addition to the tasks described above, a total of 47 tests were conducted by technical direction of the EPA Project Officer. Almost all of these were in response to requests from two government agencies in the area. For the Bonneville Power Administration, tests were run to evaluate alcohol-gasoline blends, a methanol-fueled car, and an exhaust system heat shield for a vehicle that travels off-road. For the Oregon Department of Environmental Quality Vehicle Inspection Program, tests were run on aftermarket turbochargers, a retrofit device, a gasohol fuel, and a noncomplying imported car. A total of about 6 tests were run on: a liquefied natural gas fueled pickup truck, an experimental safety vehicle, an energy storage system, and a methanol-fueled car.

Program Conclusions

The last of several modifications to the contract for Testing Support for Evaluation of I/M issues covered testing until April 15, 1982. The final test sequence in the program was conducted, as part of the Test Group 17 task, on April 14.

No final laboratory qualification procedure was conducted. Calibration and calibration checks on chassis dynamometers, constant volume samplers, and gas analyzers had been conducted on a regularly scheduled basis all through the life of the program, with EPA personnel on site. The EPA Project Officer felt that a final laboratory qualification, therefore, was unnecessary.

All test equipment was removed by the contractor and shipped to its corporate headquarters in Arizona, and the facility was vacated on May/15, 1982.

Test Results

Subject	Contact
Contractor's Test Reports on Element I, Element II, Element III, and Test Groups 1 through 17	MVEL Library
I/M Staff Reports (See "Abstracts of I/M Technical Reports and Policy")	Phil Lorang, Chief I/M Staff
Emission Factors Data Base	Lois Platte, TEB